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TITLE PAGE

Title

The Metabolic Demand of External Load Carriage in Golfers: A Comparison of a Single Versus Double-Strap Golf Bag.

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ABSTRACT

BACKGROUND: A golf bag filled with a set of clubs provides a substantial load. When carried over distance this can increase the demands placed upon the golfer, leading to discomfort, fatigue and injuries. This study aimed to compare the metabolic demands of 2 methods of golf bag carriage. ***METHODS:*** A total of sixteen healthy male recreational golfers participated in the study. Participants were given an initial familiarization session in which their self-selected walking speed was determined. This was utilized as the treadmill speed for all subsequent trials. The testing protocol consisted of 3 randomized trials of treadmill walking for 5 minutes in each of three conditions: unloaded, single-strap bag and double-strap bag. Equipment consisted of a double-strap golf bag with a standard set of clubs weighing 12.5kg. For all trials oxygen consumption ($L \cdot min^{-1}$), VO_2 ($ml \cdot kg \cdot min^{-1}$) respiratory minute volume (VE) ($L \cdot min^{-1}$), and heart rate (HR) were measured. ***RESULTS:*** Results showed that the double-strap bag required significantly less oxygen consumption (1.19±0.19 vs 1.31±0.16 $L \cdot min^{-1}$, $p<0.01$) relative oxygen consumption (14.49±2.06 vs 15.93±2.25 $ml \cdot kg \cdot min^{-1}$, $p<0.01$), reduced respiratory minute volume (29.95±4.19 vs 32.47±4.26 $L \cdot min^{-1}$, $p<0.05$), and lower heart rates (100.14±11.05 vs 106.96±9.33 BPM, $p<0.001$) than the single-strap bag. Both methods of carriage showed significantly greater metabolic demands than the unloaded condition ($p<0.05$). ***CONCLUSIONS:*** The decreased metabolic cost of carrying a double-strap golf bag may facilitate a reduction in fatigue and reduced mechanical stress. Golf bag transportation must therefore be recognized as a factor in reducing the risk of injury and improving playing performance.

Key Words

Metabolic, Cardiorespiratory, External load, Oxygen, Golf

Key Points

- A golf bag filled with clubs provides a substantial load to be transported.
- The metabolic demands of golf bag carriage are significantly higher than in an unloaded condition.
- The use of a double strap golf bag reduces the metabolic cost of load carriage in comparison to a single strap bag.
- The use of a double strap golf bag may facilitate a reduction in fatigue and mechanical stress.

INTRODUCTION

Golf can be played and appreciated regardless of age, gender, or athletic ability, and is played by over 50 million people worldwide[1]. Physically golf is a demanding game and its participation has the potential to affect a number of factors which determine health. These include longevity, cardiovascular, metabolic, and musculoskeletal system [2]. However, many golfers do not understand the risk that golf poses to body through the repetitive and cumulative nature of the game. The potential for injury is often exacerbated by people playing without an appropriate warm up, and focussing unnecessarily on power and distance. Golf includes long bouts of walking and the effort of the game depends on walking speed, distance, course design, and the method of golf bag transportation[2]. A golf bag filled with a set of clubs provides a substantial load. When carried over distance this can increase the demands placed upon the golfer, which in turn can lead to discomfort, fatigue and injuries[3]. Some golf clubs are recommending the use of a trolley to reduce the risk of back problems[4].

There is now considerable research relating to load carriage that considers metabolic[5], kinematic[6], kinetic[7], EMG[8] and subjective perceptual[9] differences. There appears to be literary consistency regarding the increased metabolic cost of load carriage and the advantage of systems that spread the load around the trunk. The metabolic demands of walking a golf course are considerable. When using a pull-cart for clubs, this has been reported to be 8.2 ± 0.2 metabolic equivalents per round, and requires 46 ± 2.6% of a golfer's functional capacity on a flat course or up to 85% on a hilly one[10]. This metabolic energy expenditure increases sharply if the golf bag is carried, and can easily double for a moderate load[11].

Load carriage can cause pain and discomfort in the lumbar and dorsal[12], lower back and shoulders[13], and cervical regions[14]. Traditional golf bags are designed with one strap that is slung over a single shoulder. Although the bag is positioned close to the centre of mass (COM), there is still significant asymmetrical loading. The increase in metabolic demands associated with asymmetrical loading can be due to changes in biomechanics, gait efficiency and muscle activation, Indeed, the forces and joint moments of walking increase markedly with load, as does the electromyographic activity of lower limb and trunk musculature[15]. This is exacerbated further if load is carried asymmetrically as a mechanism for posture adaptation is activated to maintain balance and COM[16].

Pascoe et al.[17] report that carrying a one strap back pack promotes lateral spine bending and shoulder elevation, whilst two-straps significantly reduced the carrying stresses due to the more even displacement across both shoulders. Orr et al.[18] supports the finding of unilateral load causing lateral bending of the lumbar spine. This alteration increases concavity of the opposite side, increasing the potential for spinal injuries and the activation of lower back musculature. An EMG study by Cook and Neumann[19] identified a rise in muscle activation of the contralateral muscles when load is carried asymmetrically. This in turn puts a higher demand upon the cardiorespiratory system and increased metabolic costs. Legg and Cruz[20] acknowledged a significant difference in metabolic demand when comparing oxygen uptake of soldiers carrying a single-shoulder versus double-shoulder bag. They concluded that the double-shoulder bag would result in loads being tolerated for longer due to the decreased work load. The combination of increased muscle activation and alterations in gait are thought to cause the increase in metabolic costs associated with asymmetric loading[3].

The transportation of a golf bag therefore plays an integral role in both performance outcomes[21] and injury prevalence[13]. The purpose of this study was to identify whether there were significant differences in measures of metabolic demand between walking whilst carrying a single versus double strap golf bag.

METHODS

Subjects

A total of sixteen healthy male recreational golfers volunteered to participated in this randomised cross-over study (40.8 ± 16.2 years, 180.0 ± 6.1 cm, 83.3 ± 14 kg). Prior to participation the subjects completed and signed a health questionnaire and written informed consent. Subjects were excluded from the study if they had a history of back or lower extremity pathology, neural or heart conditions, or an inability to complete a 5-minute treadmill walk. Ethical approval was obtained from University College Birmingham's Research Ethics Review Board and all procedures performed in compliance with relevant laws and institutional guidelines.

Testing Procedures

The equipment consisted of a double-strap golf bag (Ogio, Silencer stand bag) with a standard set of clubs weighing 12.5kg. The bag straps were adjusted so that the golf bag hung across the lower back for both the single-strap and double-strap trials. For the single-strap trial only the right arm was placed through the carry strap and positioned on the right shoulder. The testing protocol consisted of a single trial at each of three load conditions: unloaded, single-strap bag and double-strap bag. All subjects were given an initial familiarisation session on the instrumented treadmill (4Front, Woodway) to determine their self-selected walking speed, based on their natural ambulation. This was recorded and utilised as the treadmill speed for all subsequent trials. This ensured a natural and consistent walking gait was adopted for all participants. For all trials a heart rate monitor was placed around the chest at the xyphoid process (Polar, H7), and a face mask placed on each subject in order to collect expired gases. Subjects sat quietly for 2 minutes before testing and baseline heart rate was recorded. Subjects were initially asked to walk unloaded on the treadmill for 5 minutes at their self-selected speed. Oxygen consumption and respiratory volume were collected using a calibrated portable ergospirometry system (Cortex, Metalyzer 3B), and heart rate recorded at 30 second intervals. Subjects were allowed to rest for 5 minutes to ensure that heart rate returned to near resting levels (± 5 beats of baseline). The test was then repeated for each of the loaded conditions. The order of this was randomised for each of the subjects to limit selection bias and confounding variables.

Statistical Analysis

Mean values for oxygen consumption (VO_2, $L\cdot min^{-1}$), relative oxygen consumption (VO_2, $ml\cdot kg\cdot min^{-1}$) respiratory minute volume (VE) ($L\cdot min^{-1}$), and heart rate (HR) were calculated. A one-way repeated measures analysis of variance (ANOVA) using an alpha level 0.05 was performed on all dependent variables using Statistical Package for the Social Sciences 23 (SPSS). Mauchley's sphericity test was conducted on all ANOVA measures. The Greenhouse-Geisser adjustment was included for all outputs that violated the assumption of sphericity. Post-hoc Bonferonni corrected t-tests were used to examine multiple comparisons when the ANOVAs were significant.

RESULTS

Mean and standard deviations of oxygen consumption, relative oxygen consumption, VE and HR are presented in Table 1 for all three trial conditions. Self-selected walking speed ranged from 2.8 – 5.1 km/h (3.81 ± 0.81 km/h). Repeated measures ANOVA determined that statistically significant differences existed between all 3 conditions for VO_2 ($F_{1.802.\ 14.412} = 44.588$, $p<0.001$), $ml\cdot kg\cdot min^{-1}$ ($F_{1.644,\ 13.155} = 18.302$, $p<0.001$), V_E ($F_{1.842,\ 14.738} = 46.388$, $p<0.001$), and HR ($F_{2,16} = 33.896$, $p<0.001$). Post-hoc analysis revealed that the double-strap carrying mode required significantly less oxygen consumption (1.19±0.19 vs 1.31±0.16 L·min^{-1}, $p<0.01$) relative oxygen consumption (14.49±2.06 vs 15.93±2.25 ml·kg·min^{-1}, $p<0.01$), reduced respiratory minute volume (29.95±4.19 vs 32.47±4.26 L·min^{-1}, $p<0.05$), and lower heart rates (100.14±11.05 vs 106.96±9.33 BPM, $p<0.001$) than the single-strap carrying method. When compared to the walking trial, the double-strap carry system showed a statistically significant increase in oxygen consumption (1.19±0.19 vs 1.10±0.18 L·min^{-1}, $p<0.05$), relative oxygen consumption (14.49±2.06 vs 13.35±1.60 ml·kg·min^{-1}, $p<0.01$) and heart rate *(*100.14±11.05 vs 94.48±10.51 BPM, $p<0.001$), whilst VE showed no significant difference (29.95±4.19 vs 28.13±4.12 L·min^{-1}, $p>0.05$). Figure 1 gives a visual representation of the significant difference in metabolic demands of the three trial conditions, as measured by relative oxygen consumption (VO_2).

DISCUSSION

This study confirmed that there is a significant increase in the metabolic cost (as measured by VO_2, ml·kg·min^{-1}, V_E and HR) of carrying a golf bag and clubs when utilising a single strap method versus double strap carriage. This difference appears to be caused by the asymmetric loading associated with the single strap golf bag. Asymmetrical load alters the relationship of the centre of mass (COM) to the base of support (BOS). Postural balance is easily controlled, but becomes more difficult to control during ambulation as the body's COM shifts outside the BOS. Walking is defined as a series of processes involving the loss and recovery of balance and requires significant dynamic stability. The body's objective is the minimal displacement of the COM which optimises energy efficiency[22]. Asymmetric load displaces the location of the COM towards the loaded side, and is accompanied by gait modifications, which cause not only increased contralateral trunk flexion, but also a dominance shift in L5/S1 joint moment during normal walking[23, 24]. The asymmetrical external load associated with carrying a golf bag with the strap over one shoulder increases postural sway and the pulse rate and oxygen consumption increase. The higher energy costs related to asymmetric loading increases muscle activity and decreases gait efficiency[25]. An improvement in the symmetry of load carriage associated with the double strap golf bag requires less muscular activity to limit postural sway. This is turn leads to a decrease in the metabolic demands of the load carriage and may facilitate a reduction in fatigue that may negatively impact golf performance. These findings are consistent with those of previous studies that examined symmetrical and asymmetrical load carriage in children[26], adults[27, 28], soldiers[20], and golfers[3].

While the golf swing may not appear to be overly stressful, biomechanical studies have identified that the action requires a high degree of coordination[29], and that many body parts are moving at high velocities and extreme ranges of movement[30]. The mechanics of the golf swing may contribute to injury susceptibility[13], with less efficient and inappropriate movement patterns further increasing injury risk[31]. Indeed, club head velocity and accuracy have been seen to be reduced when players become fatigued[32]. It has also been suggested that fatigue in the latter stages of a game can lead to poor decision making, regarding shot or club selection[33], and a decline in ability[21]. As the average golf round can take 4 hours to complete[34], the reduced energy costs of carriage using a double-strap golf bag can limit this performance decline. This is due to the associated reduction in fatigue, particularly towards the end of the golf game[35].

The use of a double strap golf bag may also lead to fewer injuries. Gosheger et al.[13] reported that regular carriage of a golf bag resulted in significantly more injuries to the lower back, shoulder and ankle than those who adopted other transportation methods. Asymmetric loading increases shearing forces at the joints and compressive forces induced by muscle contractions, with the potential for acute and long-term injury being far more considerable than symmetrical load carriage[17]. Indeed, mechanical alterations such as these also may lead to, or aggravate, chronic conditions such as osteoarthritis[36]. Moreover, the shoulder takes significant greater stress amongst one strap carriers and strain is prevalent in those who do not always use both straps on a two strap bag. This is due to the same shoulder being used to carry the bag which can lead to a functional scoliosis, and a compensatory lean away from the shoulder of carriage[4].

The adaptation mechanism associated with asymmetrical loading is associated with the mass of the load[37]. It is well established that the metabolic demands per kg of load carried is equal to the metabolic demands per kg of body mass up to approximately 30kg[38]. However, it has also been suggested that the metabolic demands increase more sharply as heavier loads are carried[39]. To prevent musculoskeletal injuries, the backpack load for adolescents and college-aged young adults has been recommended to not exceed 10–15% of the individual's body weight (BW)[40]. Within the present study, the 12.5kg mass of the golf bag equates to 15% of the participant's average body weight, although this varies from 12.8 to 18.2% if the weight range of participants is included. As the study participants were all adults, the loads that they can tolerate are higher than those of adolescents. However, the high relative load of the golf bag and the increased metabolic demands of the single-strap carriage method, demonstrates that golf bag transportation must be recognised as a factor in reducing the risk of injury and improving playing performance.

CONCLUSION

The study is limited by a small sample size, although this may be disputed as statistically significant results were found. Within the study the participants were also required to walk continually for 5 minutes, and not for shorter durations that would be experienced by golfers during a real round. However, it is anticipated that the beneficial reduction in metabolic demand associated with the double-strap bag, would be increased over a full round of golf that can last 4 hours. This would allow players to play for longer and have more energy for other activities. In addition, less fatigue and reduced mechanical stress associated with the more symmetrical load carriage may lessen the risk of injury and improve performance. Although there is a benefit to fitness and weight loss of increasing the metabolic demands of load carriage, based on the findings of this study the encouragement of golfers to adopt alternative methods of club transportation may be warranted.

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TABLES

Table 1. Oxygen consumption ($L \cdot min^{-1}$), oxygen consumption by body mass ($ml \cdot Kg^{-1} \cdot min^{-1}$), respiratory minute volume ($ml \cdot min^{-1}$), and heart rate during a 5-minute treadmill walk without load carriage, and under single strap and double strap conditions.

	Walking	Single-Strap Bag	Double-Strap Bag	P-value	
	Mean ± SD	Mean ± SD	Mean ± SD	*ANOVA*	*Double-strap vs Single-strap*
VO_2	1.10 ± 0.18	1.31 ± 0.16	1.19 ± 0.19	<0.001	<0.01
V_E	28.13 ± 4.12	32.47 ± 4.26	29.95 ± 4.19	<0.001	<0.05
HR	94.48 ± 10.51	106.96 ± 9.33	100.14 ± 11.05	<0.001	<0.001